



# **NASA SSA for Robotic Missions**

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**January 14, 2009**



# Agenda



- Goddard Space Protection Overview
- Current Robotic SSA Activities
  - Conjunction Assessment (CA)
  - Commercial and Foreign Entities (CFE) Program
  - Orbital Debris
  - Space Asset Protection
- Potential Goddard SSA Activities
- Way Ahead



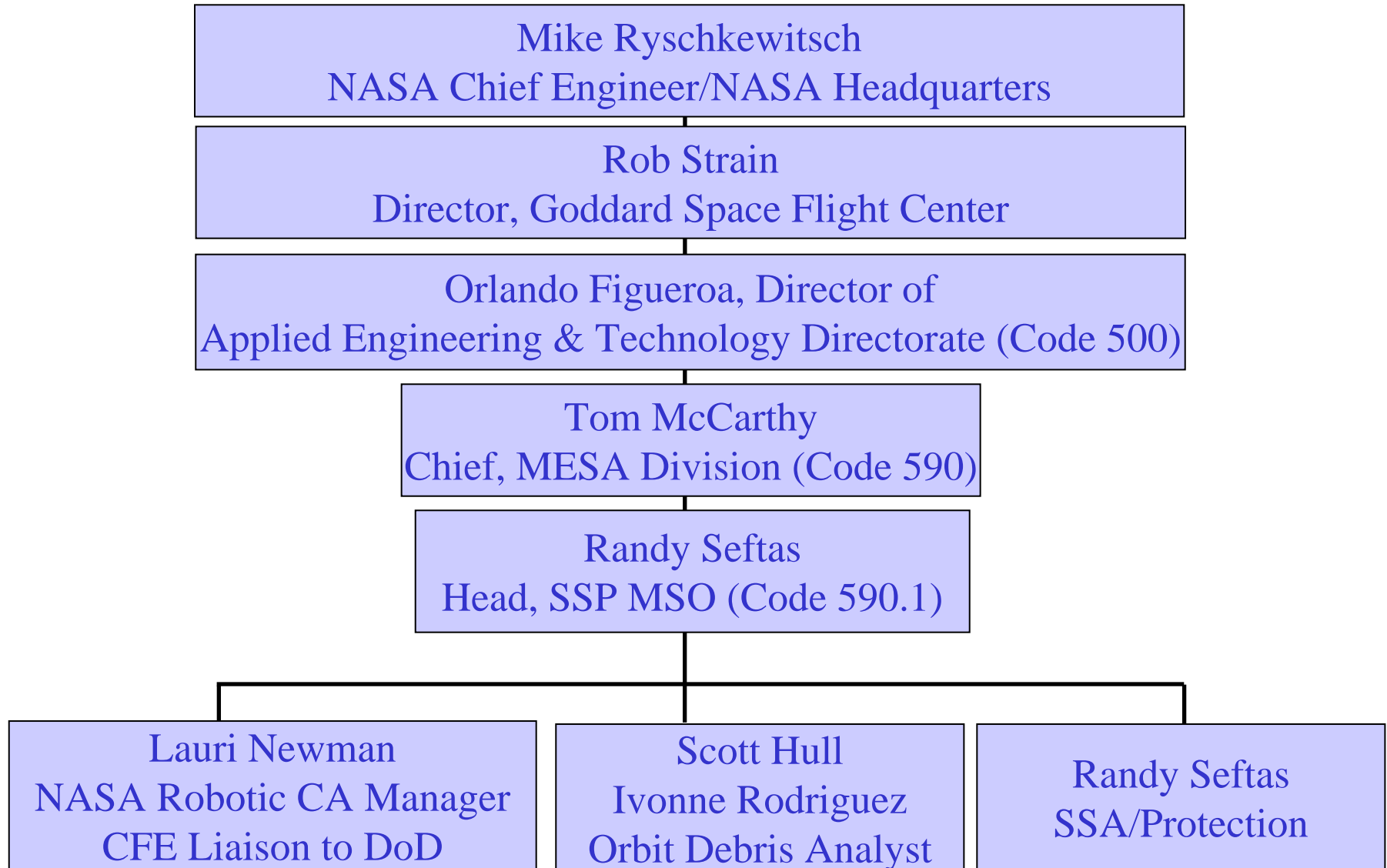
# Space Systems Protection Mission Support Office Creation



- In response to NSPD-49 and in anticipation of need, Goddard has created a Space Systems Protection Mission Support Office to provide consolidated protection services for Goddard-managed missions.
- Consolidates Goddard support for:
  - Orbit Debris Analysis
  - Conjunction Assessment/Collision Avoidance
  - Commercial and Foreign Entities Support
  - Protection of Goddard-managed missions



# Space Systems Protection Mission Support Office Organization and Reporting Chain

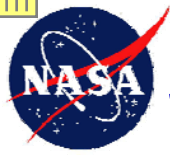




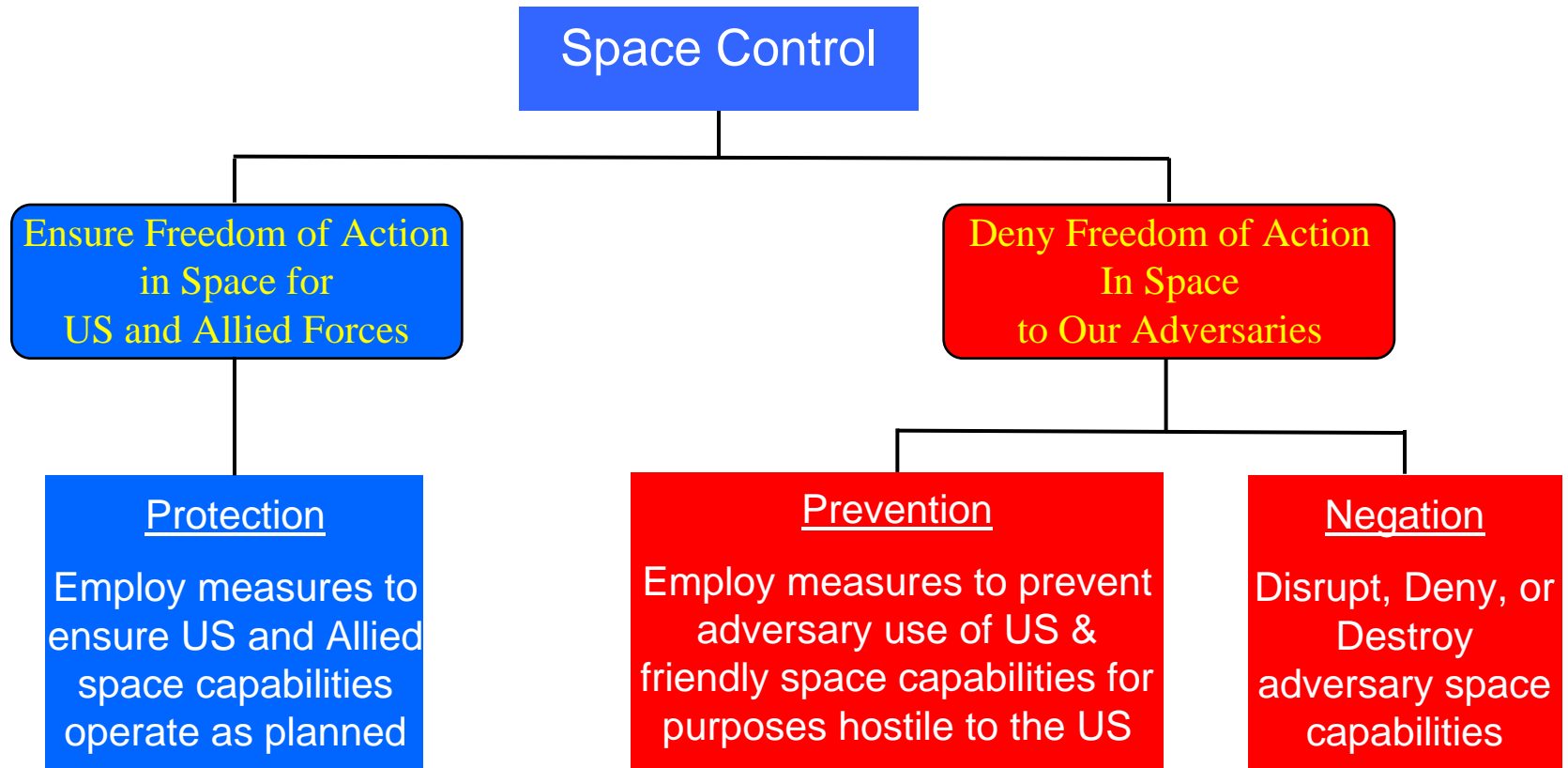
# SSP MSO Charter



- Coordinate the development and application of space asset protection activities
- Function as the sole interface between the DoD and Goddard to enable and facilitate the exchange of SSA information and data products
- Create tools & methods to protect Goddard assets
- Prepare lifecycle specific threat summaries, survivability strategies and program/project protection plans for all Goddard-managed missions.
  - Protection plans are based on each mission's survivability strategy and payload risk category.
- Perform CA for Robotic Missions
- Perform Orbital Debris Assessments and End of Mission Planning for pre-launch and operational missions to meet NASA requirements



# Space Control Objectives and Missions



## Space Situational Awareness

Historic, current, and predictive knowledge to enable decision

**Integrated Command and Control Data Fusion and Exploitation**



# NASA Goddard SSA Enablers



- GMSEC middleware automation can be developed
  - can be configured to pass telemetry in automated fashion
  - can build tools to analyze the telemetry for threats and then pass automatically to JSpOC in near real-time
- New secure facility certified for use at appropriate levels
  - Physical space to expand



# **Current Goddard Robotic SSA Activities**

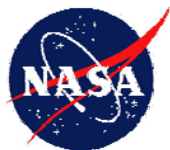




# Robotic Conjunction Assessment



- Policy for Limiting Orbital Debris (NPR 8715.6) requires routine CA for all NASA assets with maneuvering capability (signed 8/17/07).
  - *perigee height less than 2000 km or within 200 km of GEO*
- Screenings provided by dedicated OSAs at the JSpOC
- Goddard analysts use OCMs and automated s/w to evaluate threat associated with each predicted event in screening, plan avoidance maneuvers as necessary
  - Analysis of geometry, quality of OD solution, tracking resources, and Pc computation.
- Process in place since Jan 2005; new requirement is driving rapid expansion of capabilities
- Governing Documents:
  - Interagency Operating Instruction (draft in O6 coord)
  - NASA/DoD MOA – signed March 2005



# FY09 CA Customer Base



Earth Science Constellation	GEO Regime	Other NASA Missions
14780 - Landsat -5 25682 - Landsat-7 25994 - Terra 26619 - EO-1 26620 - SAC-C 27424 - Aqua 27642 - ICESat 28376 - Aura 28498 - PARASOL 29108 - CALIPSO TBD – OCO (launch ~2/09) TBD – Glory (launch ~10/09)	13969 - TDRS 1 19548 - TDRS 3 19883 - TDRS 4 21639 - TDRS 5 22314 - TDRS 6 23613 - TDRS 7 26388 - TDRS 8 27389 - TDRS 9 27566 - TDRS 10 TBD - GOES-8 (launch 11/08 – L&EO only) TBD - SDO (launch ~ 4/09)	26997 - Jason 22076 - TOPEX 25063 - TRMM 27391 - GRACE-1 27392 - GRACE-2  33053 - GLAST 33105 – OSTM/Jason-2



# Commercial and Foreign Entities Program Support [1 of 2]



- DoD funds NASA to serve as Liaison between CFE customers and USSTRATCOM
  - Provides single Point of Contact between CFE community and responsible officials at JSpOC/DoD
  - Form 1 processing – coordinate input from CFEs to ensure correct requests
  - R-15s/VIMs – collect and submit data
  - Exchange launch Forecast Information
  - Notifies USSTRATCOM of significant orbit maneuvers
- Goddard's Flight Dynamics Facility supports commercial launch vehicles and therefore has ready access to data needed for SSA by DoD.



# Commercial and Foreign Entities Program Support [2 of 2]



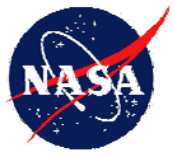
- NASA provides secure communications services to DoD through our Comm Center
  - SECRET-level facility approved by DISA
  - Houses copy of public catalog received daily in addition to other types of messages
  - Reformats data and automatically distributes it over various media per approved Form 1 requests
  - Routes two line elements (TLEs) received via the Dahlgren encrypted communications link to “Space-Track” Website.
  - Launch support: coordinates in advance with JSpOC to understand which new object numbers will be utilized for imminent launches to ensure that approved customers will be able to receive the messages in a timely manner.
  - upgrade in progress to Multifunctional Secure Gateway system from Message Distribution System
- Working with USSTRATCOM and AFSPC to define role in future CFE program.



# DoD Use of Comm Center



- NOAA (GOES, POLAR, METEOSAT, CORIOLIS, etc.)
- AF/Suitland (DMSP) receives customized TLE messages
- TLEs to Space Track website (“do not distribute” TLEs are stripped off before rest of catalog is sent)
- Send messages via military channels for distribution to entities at Wallops Island
  - Radiation Requests/Reply (from ships at sea) via Autodin routed to Wallops via email for determining frequency interference
  - Aviation Safety messages from Safety Office at Redstone Arsenal, AL. routed back to Wallops via AMDS email.
  - TLEs for ISS and Soyuz for NASA Reps at Wallops Range for antenna pointing



# Space Protection SSA



- Goddard currently does not do much SSA reporting
  - NASA sends space weather data to NOAA from various assets such as SOHO & ACE
  - “MOA Between DoD and NASA for DoD Support to NASA Spaceflight Operations” lists requirements for data exchange in detail. (signed Mar 05)
- Attempting to centralize and improve SSA data collection
  - Developing notification process for significant events to strengthen interface with DoD to ensure timely reaction to events.
- In future will work together to share knowledge and lessons learned with other NASA centers and civil agencies as appropriate to improve SSA
  - Goddard Space Flight Center is responsible for robotic assets
  - Johnson Space Center is responsible for human spaceflight
  - USGS partners with NASA to fly Landsat missions



# Orbital Debris Support

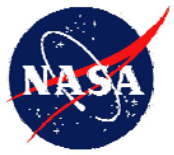


- NPR 8715.6 requires that orbital debris be limited to the maximum extent possible, through assessments of debris generation potential and disposal planning
- NASA-STD 8719.14 defines the requirements for development and operational missions
- SSP-MSO directly supports all GSFC missions with respect to orbital debris mitigation activities
- JSC/ODPO provides support to the entire agency, and serves as the technical point of contact for orbital debris and end of mission issues



# Potential Future Robotic SSA Activities





# Goals



- Share capabilities and data among government organizations for improved SSA
  - NASA looks forward to working with DoD in its role of supporting civil space in asset protection
  - NASA is both a producer and a consumer of SSA data
  - NASA is willing to share SSA data and information derived from 40+ operational missions with the DoD
  - NASA is prepared to do what is appropriate to protect our space systems
- Create strong collaborative relationship between NASA and JFCC-SPACE
  - To support JCD functional components as directed by NSPD-49
  - To resolve operational issues efficiently and quickly
  - To be actively involved in the definition of DoD-provided SSA products and services for use by NASA to enable and enhance our protection capabilities.



# NASA Capabilities [1 of 2]



- Operational Collision Risk Assessment / Avoidance Maneuver Planning
  - Probabilistic Risk assessment for 24 satellites, 12 different Owner/Operators
  - Avoidance maneuver planning for both GEO and LEO satellites
  - Expertise can be generalized to support other missions
  - Develop risk reduction maneuver strategies that account for mission-unique capabilities and constraints
- Modeling & Simulation
  - Long term evolution of debris clouds – characterization of break-ups
  - Empirical Flux Regime Characterization – estimation of expected # of conjunction events
  - Can quickly evaluate various SSN Tracking Scenarios to determine expected accuracy
  - Coverage analysis for space-based tracking
  - Analysis of covariance realism, sparse tracking, etc



# NASA Capabilities [2 of 2]



- Orbit Estimation
  - Expertise in both batch least squares and EKF
  - Currently performing OD for ~40 satellites
  - Techniques using EKF to detect delta-V maneuvers
- Re-Entry Analysis
  - Footprint targeting, maneuver design
  - Supported GRO, EUVE, and UARS reentries
- Space weather
  - Data from NASA assets could be routed to DoD in addition to current NOAA interface
  - Schatten predicts produced under contract to Goddard



# CFE/SSA in the Space Community

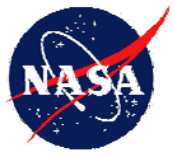


- One of the services frequently requested via Form 1 is Conjunction Assessment
- In April 2008, the AIAA Space Ops Technical Committee formed a subcommittee on Conjunction Assessment.
  - Overarching Mission: Understand and improve the state of operational conjunction risk and security.
  - Publish series of white papers
    - describing the current state of CA
    - Suggest improvements to meet community needs
    - Key topics:
      - Topic 1. The current state of Conjunction Assessment
      - Topic 2. Risk/Conjunction Model.
      - Topic 3. Risk Control Protocol.
      - Topic 4. Space Traffic Control, Notional Architecture
  - AIAA Astrodynamics Conference in Pittsburgh in Aug 2009 targeted for Topic 1 (invited session).
  - Survey to be sent to industry to collect data on current state.
- Intelsat Consortium – data center; NASA was contacted to participate



# Current CA Data to CFEs Not Sufficient

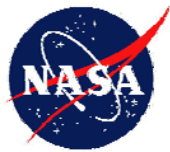
- Need way to provide service to all CFEs if CA is to be done accurately to prevent debris generation and protect all assets.
- The Problem: CFEs only have access to GP public catalog.
  - CA screenings are inaccurate, causing extra work for Owner/Operator and Air Force to investigate identified false conjunctions.
  - Some true conjunctions may not be identified at all, causing risk to all GEO users if collision occurs.
  - Planning avoidance maneuvers is iterative shot-in-the-dark process – bad for time-critical issue.
- Even use of SP catalog requires additional analysis to determine true threat of event
  - Miss distances (& Pc) currently provided by Air Force in response to Form 1 CA request are not sufficient for O/O to evaluate threat. (If maneuver is performed and miss distance was inaccurate due to high uncertainty, could cause risk to asset.) Need analysis of Orbit Determination solution by experienced analysts to determine threat and mitigation.



# Potential CFE CA Solution



- Proposed Solution: AF provides CA service similar to current arrangement with NASA/Goddard
  - Customer pays for screening service.
  - Screening results sent to “CA data evaluation center”.
  - Experienced analysts evaluate risk to asset.
  - Analysts provide 1<sup>st</sup> guess for avoidance maneuver size, timing, and/or direction to O/O.
  - O/O creates maneuver ephemeris and sends back for rescreening.
- Benefits:
  - Would improve SSA and safety of all US assets.
  - No SP data is released to O/O if U.S. Government (military or civil) operates the data center
  - DoD would gain access to ephemeris data from all O/O, improving catalog accuracy and reducing tasking load
- Goddard already provides analysis service using AF screening data to a set of users including FSOs.
  - New CFE system could be modeled on this prototype
  - Could extend services to other customers having approved Tailored Agreements



# Way Ahead



- Space Protection:
  - Continue to build relationship with DoD
    - Met with JFCC-SPACE on 09 Oct 08 to discuss potential future SSA collaboration.
    - Visited JSpOC 12/08
  - Develop automated capability to provide NASA SSA info to JFCC-SPACE in timely manner
    - White paper in development – propose fusing spacecraft engineering data to identify, characterize and distribute SSA from GSFC operational missions. Data could be passed to DoD in near real-time.
- Orbital Debris:
  - Continue to prepare Orbit Debris Assessment Reports and End of Mission Plans for Goddard robotic missions
  - Continue to build cooperation between center orbital debris specialists and SSP-MSO
- CA:
  - Investigate possible automation of CA screenings
- CFE:
  - Continue participation in evolving efforts, help in any way needed



# Summary

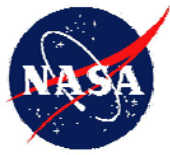


- SSA
  - Goddard can offer some data to DoD in support of the SSA effort
  - We are prepared to help and want to partner – tell us what you need
  - Goddard is prepared to do analysis, algorithm development, etc. in support of JSpOC
- As we develop the SSPMSO, if there are things we can do in support of DoD, we would like that input and will try to accommodate.
- NASA wants to be able to help define what SSA support products we need from DoD





# Backup Charts



# Project Protection Plan Template



## 1. INTRODUCTION

- 1.1 PROTECTION PLAN OVERVIEW
- 1.2 PROJECT OVERVIEW
- 1.3 ACQUISITION STATUS

## 2. REFERENCES

- 2.1 DIRECTIVES AND INSTRUCTIONS
- 2.2 REQUIREMENTS
- 2.3 STUDIES AND ANALYSES

## 3. REFERENCES

### 3.1 THREATS: HOSTILE ACTION

- 3.1.1 *Overview*
- 3.1.2 *Threat Characterization*
  - 3.1.2.1 *Cyber Attack*
  - 3.1.2.2 *Electronic Attack*
  - 3.1.2.3 *Lasers*
  - 3.1.2.4 *Ground Attack*
  - 3.1.2.5 *Asymmetric Attack on Critical Commercial Infrastructure*
  - 3.1.2.6 *Anti-Satellite Weapons*
  - 3.1.2.7 *High-Energy Radio Frequency Weapons*
  - 3.1.2.8 *Artificially Enhanced Radiation Environment*

### 3.2 THREATS: ENVIRONMENTAL

- 3.2.1 *Overview*
- 3.2.2 *Threat Characterization*
  - 3.2.2.1 *Natural Environment Storms*
  - 3.2.2.2 *Earthquakes*
  - 3.2.2.3 *Floods*
  - 3.2.2.4 *Fires*
  - 3.2.2.5 *Radiation Effects in the Natural Environment*
  - 3.2.2.6 *Radiation Effects to Spacecraft Electronics*

## 4. PROTECTION VULNERABILITIES

### 4.1 GROUND SEGMENT VULNERABILITIES

- 4.1.1 *Command and Control Facilities*
- 4.1.2 *Remote Tracking Stations*
- 4.1.3 *Spacecraft Simulator(s)*
- 4.1.4 *Mission Data Processing Facilities*
- 4.1.5 *Flight Dynamic Facilities*
- 4.1.6 *Flight Software Production/Verification/Validation Facilities*

### 4.2 COMMUNICATIONS/INFORMATION SEGMENT VULNERABILITIES

- 4.2.1 *Command Link*
- 4.2.2 *Telemetry Link (Mission Data)*
- 4.2.3 *Telemetry Link (Engineering Data)*
- 4.2.4 *Ground Network*

### 4.3 SPACE SEGMENT VULNERABILITIES

- 4.3.1 *Spacecraft Physical Characteristics*
- 4.3.2 *Spacecraft Operational Characteristics*
- 4.3.3 *Orbital Parameters*
- 4.3.4 *Optical Devices (Sensors/Transmitters/Receivers)*
- 4.3.5 *Communications Subsystem*
- 4.3.6 *Command and Data Handling Subsystem*
- 4.3.7 *Instruments*

### 4.4 LAUNCH SEGMENT VULNERABILITIES

- 4.4.1 *Launch Parameters*
- 4.4.2 *Launch Site Integration and Test Activities*

### 4.5 COMMERCIAL INFRASTRUCTURE VULNERABILITIES

- 4.5.1 *Electrical Power*
- 4.5.2 *Natural Gas*
- 4.5.3 *Telecommunications*
- 4.5.4 *Transportation*

## 5. PROTECTION COUNTERMEASURES

- 5.1 SURVIVABILITY STRATEGY
- 5.2 MISSION THREAT MITIGATION
- 5.3 MISSION RESTORATION OPTIONS
- 5.4 MISSION SURVIVABILITY CHARACTERISTICS

## 6. DEBRIS MITIGATION

- 6.1 DESIGN GUIDELINES
- 6.2 END-OF-LIFE MITIGATION PROCEDURES
- 6.3 COLLISION AVOIDANCE

## 7. CRITICAL PROGRAM INFORMATION (CPI) AND TECHNOLOGIES

- 7.1 CRITICAL PROGRAM INFORMATION ELEMENTS
- 7.2 CRITICAL INFORMATION PROGRAM

## 8. PROGRAM PROTECTION COSTS

- 8.1 SYSTEMS TRADES ANALYSES
- 8.2 COST/BENEFIT ANALYSES



# Risk Assessment by CA Team



- Screening data is analyzed in two distinct ways
  - Routine Operations
    - Daily activity to assess most recent delivery of close approach predictions
    - Disposition conjunctions as a “threat”, “not a threat”, or “monitor” event based on analysis
  - High Interest Events
    - Events that have significant potential to be a threat or provide a unique analysis opportunity
    - Trending of orbit determination parameters and conjunction geometry
    - Probability of Collision Sensitivity analysis
    - Risk Mitigation Maneuver planning



# High Interest Event Risk Assessment



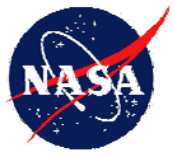
- $P_c$  and miss distance data alone cannot be used to fully assess the threat
- Additional analyses to help establish and quantify risk include:
  - Orbit determination (OD) consistency from solution to solution
    - Number of tracks and observations
    - Ballistic Coefficient
    - Solar Radiation Pressure Coefficient
    - Energy Dissipation Rate
    - Radar Cross Sectional Area
  - Probabilistic Risk Assessment Analysis
    - Realistic probability calculations based on 'realistic' state and covariance predictions
    - $P_c$  evolution as the time to the close approach event gets shorter
    - $P_c$  sensitivity analysis based on changes to inputs
  - Conjunction Geometry (clock angle, approach angle)
  - Position of hard body radius with respect to the 3-sigma covariance ellipse



# The Collision Assessment System



- Collision Assessment System (CAS) was developed to store and analyze the large volumes of data received.
- CAS is automated and comprised of several elements:
  - Secure File Transfer Protocol Server
  - Parser / Monitor Scripts
  - Database
  - Collision Assessment and Mitigation (CAM) Tool Suite
  - Secure Website
  - Configuration Management System



# Collision Assessment and Mitigation Tool Suite



- The CAM Tool Suite is the part of CAS that provides analysis utilities
- The CAM Tool Suite consists of 6 modules:
  1. Conjunction Visualization Script
  2. 2-D Collision Probability Utility
  3. Monte Carlo Simulation
  4. 3-D / Curvilinear Collision Probability Tool
  5. Time History Trending Utility
  6. Collision Avoidance Planning Tool
- The modules are built using FreeFlyer™ and Matlab™
- Output from tools is formatted into a single PDF report for each OCM



# Current NASA/GSFC Support: Liaison Function



- Provides single Point of Contact between CFE community and responsible officials at JSpOC/DoD
  - While points of contact in the DoD world change frequently, NASA has provided a stable interface for many years, so the community knows who to contact for support
  - Valuable contacts and excellent rapport are maintained among government and commercial customers
- Provides technical coordination to non-DoD customers in preparing data requests and obtaining DoD support.
- Goddard is uniquely qualified to provide this support because we have in-house access to NASA payload and commercial launch vehicle data within our Flight Dynamics Facility (FDF)

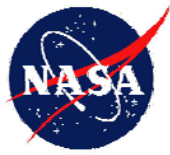


# Liaison Functions [1 of 2]



- Coordinates all NASA and CFE Form 1 Requests
  - Ensures form is correct and complete, clarifies requests
  - Coordinates required data formats, delivery mode, data frequency
  - Ensures proper handling of sensitive data
  - Facilitates required discussions between DoD and customer to resolve any open items
  - Coordinates approved Form 1s with all parties after approval and comm center is notified of approved requests
  - Tracks status of all requests until decision is received, maintains records of all approved Form 1s





# Liaison Functions [2 of 2]



- Coordinates Vehicle Information Message (VIM) / R-15 Submissions
- Coordinates notification to USSTRATCOM by CFEs for significant spacecraft maneuvers, launches, anomalies, etc.
- Anomaly resolution support
  - Liaison facilitates rapid Form 1 submission to get USSTRATCOM emergency support.
- Launch Support
  - Liaison provides real-time launch support to ensure all requested data is received
  - Exchanges Launch Forecast information with USSTRATCOM
  - Coordinates launch slips and/or schedule changes – re-issue Form 1s and VIM data as required.
- Coordinates Encrypted Circuit Communication Line Issue Resolution with Dahlgreen, Goddard Comm Center, and Cheyenne Mt. Tech Control



# Summary of Comm Center Functions



- **Routine Support**
  - **Unclassified TLEs through Goddard Network Integration Communications Center to specified customers.**
- **Non-Sensitive Launch Support**
  - **USSTRATCOM sends new TLE information for new objects according to Form 1 requests. Goddard Communications Center forwards the new TLE information to approved customers and to the Space-Track Web site.**
  - **Router Information must be correct on Form 1 in order for the Customer(s) to received data requested.**
- **Sensitive Launch**
  - **USSTRACOM does not send the TLE information for new sensitive objects until coordination has been completed with Goddard Liaison and Communications Center.**



# Current NASA/GSFC Support: Comm Center Functions



- SECRET-level facility approved by DISA
- Provides automated real-time distribution of USSTRATCOM products to approved Form 1 customers.
- Uses encrypted data transmission line through Dahlgreen
  - Bandwidth problem causing data dropouts as identified by Cheyenne Mountain Tech Control



# Comm Center Functions



- Not just bent pipe – value added services provided
  - Reformatting
    - Strip single TLEs from multiple-TLE messages for distribution
    - FDF data reformatted to remove headers and sent to SPADOC
  - Handles distribution across various media types (email, FAX, teletype...)
  - Keeps database of approved Form 1 requests such that data is automatically forwarded to customers when updates are received
  - Launch Support
    - Comm Center coordinates in advance with USSTRATCOM to understand which new object numbers will be utilized for imminent launches to ensure that customers with approved requests will be able to receive the messages in a timely manner.



# NASA Issues



Issue	Human Space Flight Support DOCUMENTS	Robotics Support DOCUMENTS	NOTIFICATION PROCESS for SIGNIFICANT EVENTS
SSA Data Sharing			
•Ephemeris data	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard Robotics IOI	OSA and FDO/TOPO
•Launch Safety and Recovery	SI 534-6	SI 534-6	
•Environmental/Space Weather			
•Maneuvers	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard Robotics IOI	OSA ,FDO/TOPO, CAA
•Breakups	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard IOI for Robotics Support	OSA ,FDO/TOPO, CAA
•Conjunction Analysis/Collision Avoidance	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard IOI for Robotics support	OSA ,FDO/TOPO, CAA
•Characterize, assess & resolve anomalies (EMI, RFI are subsets)	Building annex for next revision of STRAT/NASA OSO HSF OI		???
•NASA partners <ul style="list-style-type: none"> <li>◦ Applicability of NASA agreements</li> </ul>	RM for Human Spaceflight	JFCC SPACE CA Data RM for NASA Robotics Missions.	Other civil agencies (USGS, NOAA) ISS partners (Russia, Japan, Canada, ESA primary – AEB (Brazil) and ISA (Italy) STS partners (mission dependent). ESC partners (France, Argentina, Germany)



# NASA Issues cont




Issue	Human Space Flight Support DOCUMENTS	Robotics Support DOCUMENTS	NOTIFICATION PROCESS for SIGNIFICANT EVENTS
Notification Process for Significant Events (primarily limited to safety of flight, not EMI)	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard IOI for Robotics support	
Event Reporting Timeliness Standards Data	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard IOI for Robotics support	
Types/Formats/Transmission Means	STRAT/NASA OSO HSF OI	JFCC SPACE/NASA Goddard IOI for Robotics support	



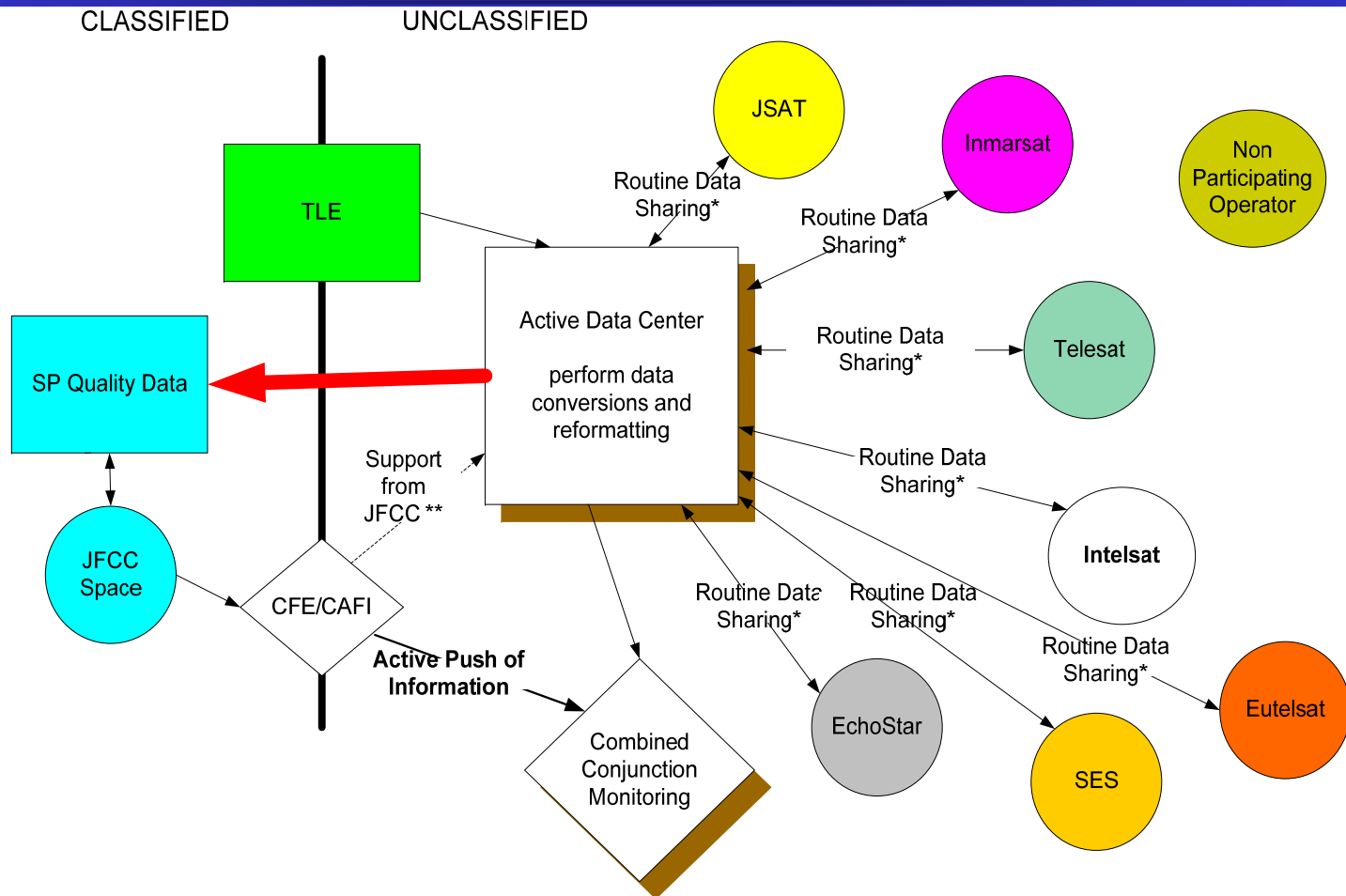
# JFCC SPACE Issues



Issue	Documentation or Proposed action	Resolution/Way Ahead
<b>Security Considerations</b>		
•Operational – NASA limited to Sensitive-but-Unclassified (SBU)	RM 's or NASA Human Spaceflight and Robotics Missions	
•ITAR	RM 's or NASA Human Spaceflight and Robotics Missions	
<b>Resources – Level of Support Requested Vs. :</b>		
•Manpower	PWS/SOO/SOW Support Agreement between AFSPC and NASA/GSFC	
•Funding		
•Equipment		
<b>Launch cooperation from NASA for non-domestic/non-cooperative launches</b>	Advance collaboration or notification to support building ELSET 1	 Microsoft Office rd 97 - 2003 Docum



# Intelsat Proposed CA Data Flow – Phase 2



\* via individual ftp site

\*\* To resolve close approach and avoidance maneuver planning

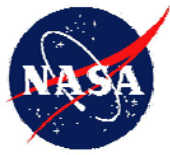




# ESC Risk Mitigation Maneuvers Performed



Asset	Secondary	Maneuver Date	Minimum Total Miss (m)	$P_c$
Terra	14222 (SCOUT G-1)	21-Oct, 2005	37	6.82E-2
PARASOL	81257 (Analyst SAT)	16-Jan, 2007	43	1.51E-3
SAC-C	14345 (SL-8 DEB)	16-Feb, 2007	57	3.40E-6
Terra	31410 (FENGYUN 1C DEB)	22-Jun, 2007	18	1.58E-1
CloudSat	28893 (SINAH 1)	04-Jul, 2007	38	2.24E-2
Aura	1399 (TRIAD 1 Debris )	26-Jun, 2008	11	4.80E-1
CloudSat	8542 (Delta I Debris)	20-Jul, 2008	90	1.77E-3
PARASOL	31293 (FENGYUN 1C DEB)	19-Oct, 2008	82	2.11E-2



# Space Situational Awareness Tasks



- **Environmental Information**

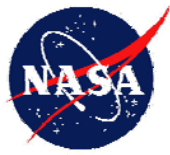
1. Monitor, characterize, predict and report on the space related environment, i.e, *terrestrial weather; atmospheric, ionospheric, magnetospheric, solar and interplanetary conditions.*
  - Goddard “Push” space weather data
  - Goddard “Pull” TBD

- **Orbital and Network Information**

2. Detect, track, identify and catalog man-made objects in space
  - Goddard “Push” state vectors for operational missions to ease burden on SSN
  - Goddard “Pull” catalog data to support in-house collision avoidance
3. Provide battle-space information and services
  - “Pull” signal/laser de-confliction and space network nodal analysis

- **Event Information**

4. Detect, process and report space events, i.e, *launches, orbital maneuvers, break-ups, reentries, orbital decay, dockings, etc.*
  - Goddard “Push” maneuver data for operational missions, launch forecast
  - Goddard “Pull” breakup data for CA analysis



# Space Situational Awareness Tasks (cont)



- **Event Information (cont)**

5. Characterize, assess and resolve anomalies/attacks on all space systems, i.e, *provide I&W of attacks, support resolution of anomalies, provide sufficient information to attribute source of attack/interference, etc.*
  - “Push” operational status of Goddard missions, anomaly reports
  - “Pull” technology (sensors and automation) that supports DoD capabilities for generating event information

- **US Space System Information**

6. Maintain the status and characteristics of Blue Space Forces/Assets, i.e, *physical properties, current status, vulnerabilities, constellation composition, etc.*
  - “Push” operational status and vulnerabilities of Goddard missions
  - “Pull” same/similar bus engineering/operations information to assist in fault isolation and anomaly resolution of Goddard spacecraft.



# Space Situational Awareness Tasks (cont)



- Space Intelligence Information

7. Provide intelligence on foreign and adversary space systems, i.e, *space related communications links, on-orbit asset locations, etc.*
  - “Pull” intelligence information when required to protect Goddard missions.
8. Maintain current foreign and adversary space system characteristics and operating parameters, i.e, *physical and signal properties, function, signal internals and operating parameters, etc.*
  - “Pull” intelligence information when required to protect Goddard missions.
9. Detect, monitor and report on foreign and adversary terrestrial space systems, i.e, *fixed and mobile systems for command and control, launch and exploitation, etc.*
  - “Pull” intelligence information when required to protect Goddard missions.
10. Develop predictive battle-space awareness on adversary strategies, tactics, intent, activity, and knowledge, i.e, *identify adversary centers of gravity, likely courses of action, strengths and vulnerabilities to support targeting and intelligence collection, etc.*
  - “Pull” intelligence information when required to protect Goddard missions.